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A GENERALIZED MISSION DESCRIPTION FOR MANNED SPACE FLIGHT

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I. INTRODUCTION

On the basis of the current successes in the Mercury program and the extensive program planned for Apollo, it is clear that man does have a role in space. Yet the exact nature of his role and the requirements for his support still remain to be specified. This report represents the first phase of a research study undertaken to clarify further the human information and control requirements for manned space flight and to evaluate the effectiveness of feasible control-display concepts in meeting these requirements.

Phase I of the study as contained in this report deals with an analysis of a "generalized" mission in a manned vehicle. The vehicle is unspecified in detail in the hope that the results of the over-all study will not be tied to a specific collection of hardware but rather will have broader applicability. The study does assume, however, that the vehicle is capable of control and is maneuverable and contains all the systems, primary and redundant, necessary to support the mission. A full exposition of the concept of a "generalized" mission will be developed in the following section of this report.

In the literature concerned with space flight two opposing viewpoints emerge regarding the potential contribution of man to the space mission. Several sources maintain that man cannot contribute much, if anything, to the success of a mission; he can perform no useful function and, in fact,

will be merely a passenger. In contrast to this, others feel that man must be an integral part of the system operation and that to leave him out would compromise the reliability and, thus, the probability of success of the mission. The latter view is the position taken in this study. Man possesses inherent capabilities which can be brought to bear fully in manned space flight. Thus, our problem is not whether to include man or not, but rather how to best utilize his capabilities by effectively allocating functions between man and machine. With proper integration of man into the system, the added flexibility and reliability of man's performance can contribute meaningfully to the success of a mission regardless of its ultimate purpose.

It is held by most sources that man's business in space is scientific investigation. Aside from the sheer adventure of extraterrestrial flight, the tangible and truly valuable benefits to be derived from such flights are the increased knowledge and understanding of our world and our solar system. It would appear then that ultimate descriptions or characterizations of space missions should be in terms of the scientific objectives of those missions or even more explicitly in terms of specific investigations to be conducted. However, we must recognize the prerequisite of "getting there and getting back" as essential to the success of any mission. Therefore, in this study, an initial step in the determination of requirements will emphasize the "transportation" objective of a mission dealing primarily with navigation and control rather than its specific scientific purpose.

The area of concentration will be navigation and control and the subsystems for propulsion management insofar as they affect these aspects of the mission. Some detailed attention will be given to environmental control as a necessary support to the over-all mission. Finally, we will treat communication and scientific observation in sufficient detail to point out their influence on navigation and control functions.

Even in a study which attempts some general applicability, some basic assumptions must be made to define the scope of the effort. This study will confine its considerations to missions within the solar system. Interstellar or intergalactic missions present problems of a different order of magnitude and are not seen as within the scope of this research.

In keeping with the "generalized mission" philosophy employed here, the vehicle is also treated as a non-specific configuration. Thus, no precise definition of means of propulsion, booster types, number of stages, sensors available, crew size, etc., is adhered to rigidly. The vehicle is seen, however, as a "self-contained" system, i.e., one which, although it fully utilizes ground sources of data, is not dependent upon such sources for mission success.

II. MISSION ANALYSIS

A. General Approach

The first task in the development of control and display requirements for a manned space vehicle is to state the mission of the vehicle. From this statement may be derived a set of mission requirements. Mission requirements as used here refer to those conditions or events which must be achieved in a prescribed sequence to successfully complete the mission.

This specification of events can then be ordered into mission phases. The beginning and end of each phase is specified in terms of an event in the over-all sequence. For example, "injection into orbit" signifies the end of the "launch" phase and the beginning of the orbit phase. Such events can then be characterized by the conditions necessary for their occurrence or achievement. At this point, it is important to identify those functions or activities which could conceivably involve or require a human operator. This brings to bear knowledge of the capabilities and limitations of the human. Defining and organizing these functions results in a task or activity analysis for the operator(s) in the system. The activity analysis provides, in turn, a basis for formulating information and control requirements for human participation in the system functions.

Control and display concepts can then be generated and/or evaluated against the information and control requirements thus developed.

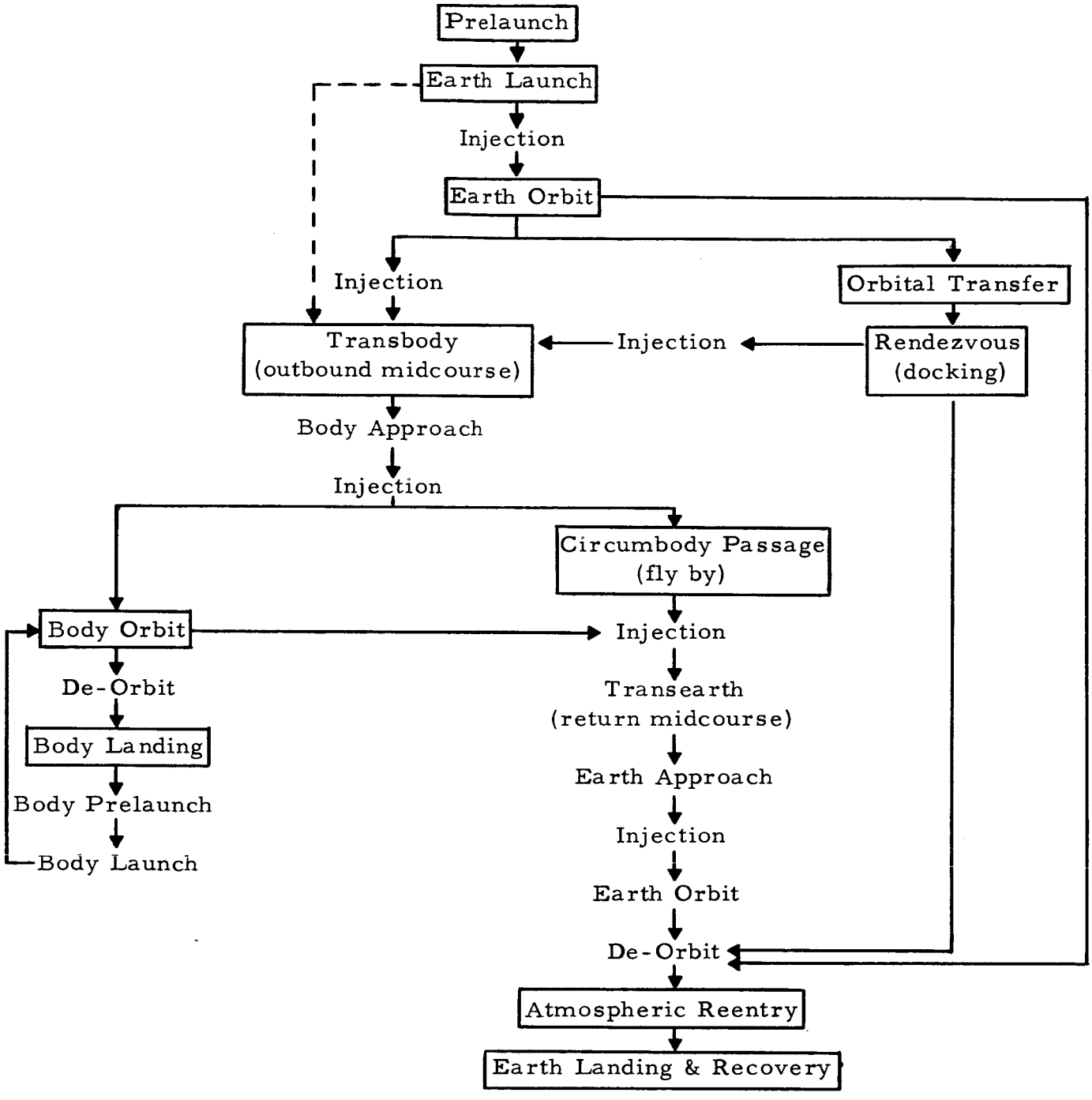
It is important to point out that the mission requirements derived in this study are not confined to a specific mission statement as contained in some earlier reports of this nature. For example, a typical mission statement might be as follows: a vehicle is to be launched into orbit; it will effect a rendezvous with an orbiting target satellite; it will then depart from its orbit, make a controlled re-entry into the earth's atmosphere, and land at a designated point on earth. Another, different mission statement might be: a vehicle will be launched into a parking orbit; at a preprogramed time it will depart this orbit and assume a translunar trajectory; upon approaching the lunar force field it will assume a parabolic trajectory and execute a fly-by of the lunar surface; it will then assume an appropriate return-to-earth trajectory; completing the return-to-earth journey, it will make a controlled re-entry and effect an earth landing at a predesignated point. Similar kinds of statements can be made for lunar orbits, lunar landings, and interplanetary voyages and landings. Clearly, the specific mission requirements may differ for different mission statements. If mission requirements derived from a specific mission statement such as those described above are used to form the basis for a subsequent development of control-display requirements, the requirements thus derived may also be specific to the mission statement. Studies following this approach would then be limited in their generality. In an attempt to overcome this limitation, a generalized mission concept was developed to form the basis for a study of control-display concepts which would

have some broad application. The generalized mission concept, as used in this study, incorporates the essential elements of all missions up through and including planetary landing and return.

The initial step in the development of the concept was to identify those aspects or phases of manned space flights which are common to all the missions. For example, all missions can be considered to have a prelaunch and a launch or boost phase. Similarly, re-entry, landing and recovery are common to all missions. Thus, these phases are identified as: "mission-common."

To insure comprehensiveness, one must then consider the range of different missions and identify phases particular to each mission which must be included in a generalized concept. These phases are described as: "mission specific." This study considers three general classes of mission, i.e., the earth orbit, the orbital rendezvous, and a "transbody" flight. Within these classes, phases can be specified which are representative of all missions in the class.

Table 1 shows the development of the mission phases in the generalized mission concept. From this diagram were drawn the phases for study in this report. It should be noted that in Table 1 the more general comprehensive term, "transbody," is used rather than "translunar" or "transplanetary." The use of this term simplifies the diagram without limiting its scope. It is important to point out that the generalized mission is not conceived of as



Notes:

□ - Signifies phases which have been incorporated into the generalized mission.

– – – – - A direct boost into a transplanetary trajectory does not appear practical at this time.

Table 1. Development of the Generalized Mission Concept.

a single, all-inclusive mission but, rather, as a concept representative of a number of individual missions. Organized in this way, a study with more general application is feasible.

B. Mission Phases

1. Prelaunch - In describing mission requirements, the term "prelaunch" has been used to identify all activities which occur in order to checkout and prepare the entire system prior to booster stage ignition. These activities at present might start many days before the actual launch. They will include such specific items as launch vehicle preparation and checkout including vehicle positioning, fueling and guidance system checkout, activation and checkout of tracking stations, checkout of the ground control center, and an entire vehicle subsystem checkout. However, for the purposes of this study, the prelaunch phase begins when the vehicle crew enters the space vehicle. It will include only those activities in which the crew will actively participate. Activities performed in the ground control station and tracking centers will only be included to the extent they affect the tasks performed by the vehicle crew. The completion of this phase is signified by the onset of booster ignition followed by vehicle lift-off.

2. Earth Launch - The launch phase includes the activities which take place in the time between lift-off and achievement of the planned earth orbit. It is anticipated that during this phase of the flight the vehicle will follow a

precomputed trajectory and that a guidance system will monitor the vehicle's progress along the launch trajectory and automatically provide correction inputs to the system which will enable the vehicle to maintain the required attitude, direction, and velocity until injection into the planned earth orbit. For planetary missions, the launch phase might be continuous through to the transplanetary trajectory. However, in terms of mission planning, a direct shot launch would place severe restrictions on launch time. In addition, the thrust limitations of presently planned boosters place severe constraints on the payload capability of such a launch. For these reasons the direct trans-body launch will not be considered in this study. The launch phase, therefore, normally terminates after insertion of the vehicle into earth orbit.

3. Earth Orbit - The earth orbit phase begins after the firing of the final injection stage and achievement of the desired earth orbit. During the orbital phase the vehicle attitude may be corrected and changed to meet orbital mission requirements and to position the vehicle for subsequent phases (i. e., orbital transfer, de-orbit). During this phase the vehicle operator will have full control of all major vehicle subsystems.

4. Orbital Transfer - From an earth orbit specific mission requirements may dictate the need to transfer the vehicle from one orbit to another to effect a satellite rendezvous or from an initial orbit to a translunar or transplanetary trajectory.

5. Docking - Following orbital transfer in the rendezvous mission, the manned vehicle will be required to make physical contact with, and (mechanical) attachment to, a target vehicle or achieve a terminal orbit which approximates that of the target vehicle to a degree which will maintain the manned vehicle within a selected proximity range of the target vehicle. In this study both of these terminal rendezvous phases will be called "docking." A condition that must exist for satisfactory completion of this phase is correspondence of the orbital elements for both vehicles within very close tolerances.

6. Transbody (Midcourse) - For lunar and interplanetary missions a midcourse phase will follow the orbital transfer phase. This phase will terminate when the vehicle enters the gravitational influence of the moon or target planet or when the vehicle reaches some predetermined range from the target body. During this phase the vehicle will follow a free fall trajectory, however manual control will be possible to allow for corrections in the programed flight path.

7. Circumbody - Upon reaching a point in the transbody phase (dependent on either range or body influence) a retrograde action will be initiated which will cause the vehicle to assume a parabolic flight path around the body. The initiation of this retrograde signifies the start of the circumbody phase of flight. On completion of the flyby the vehicle will again reach a given range from the body at which time the return midcourse phase will commence.

8. Body Orbit - This phase is similar in many respects to the circum-body phase. However, here, upon reaching a given point with relation to the body, the initiated retrograde signal will result in a planned orbit around the body. Completion of this phase will occur when either of two events take place: 1) de-orbit to effect a landing; or, 2) injection into a transearth trajectory.

9. Body Landing - It is expected that before attempting a landing, at least one orbit of the body will be carried out in order that the preplanned landing site can be inspected and confirmed. Upon confirmation of the landing site an appropriate retrograde maneuver will be programed. The landing phase will begin an activation of the retrograde thrust program. The activities performed during the landing phase will depend on the vehicle configuration and the atmospheric conditions of the body. The landing phase will end upon successful touchdown on the body. (Note: In this study activities related to body prelaunch and launch for return-to-earth phases will be treated in this phase under landing and launch subsystem.)

10. Atmospheric Re-entry - Re-entry into the earth's atmosphere will most likely be preceded by an earth orbital phase similar to that used prior to orbital transfer or injection into a transbody trajectory. The re-entry phase will commence with the departure from orbit and initiation of a retrorocket thrust program. The de-orbit activities will require extreme

accuracy and timing to insure re-entry without excessive overheating of the vehicle as it penetrates the effective atmosphere. The re-entry phase terminates upon achieving a "safe" velocity at which aerodynamic flight can be achieved or drag mechanisms can be deployed.

11. Landing and Recovery - The final mission phase is a successful landing at the designated landing area. The means by which this event is accomplished will depend on the type vehicle. In some cases the vehicle will not be capable of controlled aerodynamic flight. For such vehicles parachutes or some other drag mechanism will be employed and the actual touchdown site will be dependent mainly on the point of entry into the effective atmosphere. For landings of this type recovery techniques will be employed to retrieve the vehicle and its crew. Missions using glide vehicles will place a lesser demand on the specifications of the point of re-entry and touchdown can be accomplished at a predetermined landing site using techniques presently employed for "deadstick" landings of high performance aircraft.

C. Vehicle Subsystems

The above section identifies the necessary conditions which delineate the mission phases. The next step in the analysis is to classify the total vehicle complex into subsystems. This allows the subsequent assignment of functions to specific aspects of vehicle operation. Subsystem classification in some cases may appear to be arbitrary. Admittedly, there is

some overlap between the functions subsumed in one category or another. Where such ambiguity is felt to exist, clarification is made in the subsystem description.

1. Navigation and Guidance Subsystem - The navigation and guidance subsystem is concerned with establishing the location and flight path of the vehicle in space, determining deviations from preprogramed orbits or trajectories, and calculations of corrections to overcome such deviations. The subsystem will provide equipment for complete on-board navigation measurements after insertion of the vehicle into its initial earth orbit. Prior to insertion into orbit the trajectory may be automatically or ground controlled. It is expected that on-board measurements will be made inertially, optically and by electronic sensing (e. g. , radar). An inertial system will be used during periods when the vehicle is under the direct gravitational influence of any given body. During midcourse or free fall phases, measurements will be made using manual or autosextants in conjunction with accelerometers and free gyros. A telescope and/or periscope may be used to provide visual fix data and pretouchdown visual information. Radar or similar equipment will be provided for use during terminal landing stages. Included should be a long-range radar altimeter and a doppler radar system. Redundant systems will be provided for emergency use and increased reliability. On-board computations will be performed using digital and analog computers in addition to manual navigational aids.

2. Attitude Stabilization and Control Subsystem - The stabilization and control system is concerned with vehicle orientation with reference to the coordinate system appropriate to the mission or mission phase. Manual control of attitude will be accomplished with reference to appropriate displays by attitude, attitude rate, or angular acceleration commands. A capability for changing reference systems will be provided dependent upon mission requirements and phase within a given mission. Appropriate control systems will provide several modes of operation to enable the operator to exercise the required amount of manual rate control. In addition, the control system will also provide for automatic stabilization by accepting commands directly from the navigation and guidance subsystem.

3. Propulsion Subsystem - The number and types of propulsion subsystems required will depend largely upon the type of mission for which the vehicle is to be used. However, certain propulsion systems will be common to all missions. Included for consideration here will be the main booster stages, attitude control forces, retrograde propulsion and escape systems. For specific missions additional systems will be required such as extraterrestrial landing and launch systems and rendezvous and docking propulsion. Orbital transfers, planetary orbits and parking orbits will also impose additional propulsion requirements. Crew tasks in regard to these systems will include fuel management, thrust programing and the

manual activation and cut-off of appropriate systems. It is not expected that the vehicle crew will have any control over the booster stages during launch other than monitoring performance for abort decisions.

4. Environmental Control and Life Support Subsystem - This subsystem can be divided into five categories: a) Internal Atmosphere, b) Water, c) Nutrients, d) Sanitary Facilities, and e) Personal Protection.

a. Internal Atmosphere - Any life support system must be capable of maintaining an inhabitable internal atmosphere. The means of achieving this will depend, to a great extent, on mission duration. For short orbital missions an open system similar to that presently used in high altitude aircraft may be adequate. For such a system, supplemental oxygen is added to inspired air and the oxygen rich expired air is exhausted. For mission durations up to about one month, studies have shown that a semi-closed system in which the addition of make-up oxygen to the expired air would be required. Carbon dioxide, water vapor and odors would be removed and oxygen would be continuously recirculated. Liquid oxygen and a regenerable carbon dioxide absorbent would most likely be employed. For missions of longer durations, a closed system which could regenerate oxygen from exhaled carbon dioxide and condense water vapor for re-use would be optimum.

b. Water - A water regeneration system will be required for all but the shortest missions. Compression and vacuum distillation of water from urine and contaminated utility water have been considered because of the high quality of the recovered water and high system reliability. Studies have indicated that vacuum distillation systems are advantageous for a crew of one or two, whereas compression distillation is favored for crew sizes larger than two.

c. Nutrients - Man will require approximately 500 grams of food per day. Food should have high caloric content per unit weight and require no refrigeration. The food must be protected from contamination due to moisture and atmosphere. Aids for handling and consuming food under conditions of weightlessness will be required. Food warming units may be desirable for extended missions, but should not be required for those of limited duration.

d. Sanitary Facilities - A hand-operated pump for fecal collection has been suggested, while urine can readily be collected in a bellows-type collapsible container. Such a system was found desirable on the basis of sanitary operation, physiological acceptance, and simplicity. Under conditions of weightlessness it appears that the most promising means of washing the body would be by the use of soap-impregnated sponges and rinsing sponges. Special devices for saturating the sponges and for recovering dirty water will be required.

e. Personal Protection - Consideration must be given to protecting the crew or compensating for environmental factors in the vehicle cabin which will affect human performance and physiological well being. Pressure suits and/or pressure compartmentalization will be required for protection against sudden decompression. Insulation and vibration damping structure must be provided in the vehicle cabin to limit excessive noise levels in the environment and to maintain vibrations within acceptable limits.

Protection against high acceleration forces experienced during certain mission phases must be achieved by body position and restraint systems. The effects of prolonged conditions of subgravity have not yet been determined, however, aids to body locomotion may be required. In addition, restraints may also be required under conditions of weightlessness, especially when sleeping or manipulating controls. Radiation protection for space flights will depend on the areas of space through which the vehicle will pass and on the specific mission and trajectory of the vehicle.

5. Communications - The communications subsystem will provide a continuously available voice link between the vehicle and earth control stations. In addition, television may also be employed as a visual communications link for certain missions. Redundant systems will be provided for reliability. Telemetered data may also be transmitted to provide the vehicle with additional or redundant information where extreme accuracy and reliability are required. A full crew intercommunication system will also be provided. Rescue and recovery aids will include radio beacons and transceivers.

6. Scientific Observations - Instrumentation for scientific observation will be provided as dictated by the specific mission plan requirements. Sensors for automatic and manual data gathering will also be installed as required by mission requirements. Some general observations and measures will be made on most all missions. These may include: solar-flare detection, pressure and temperature variations, radiation measurements and meteoroid detection. It can be expected that photographic cameras and tape recorders will be used to provide audio and visual documentation of the entire mission. The crew will be able to manually select camera frame rates and recorder speeds and replace film or tape reels.

7. Emergency and Abort Subsystem - An escape system will be provided in the event of failure of the launch vehicle during the atmospheric phase of the launch. The system will function on either crew command or from an automatic abort signal. Following booster separation an abort decision may be largely in the hands of the crew member(s). One of the primary tasks of the crew during all subsystem mission phases will be to monitor vehicle instrumentation in order to identify quickly emergency situations should they occur.

8. Landing and Launch Subsystem - The specific configuration of items included in the landing and launch subsystem will be entirely mission-oriented. They will consist of the following: earth landing, extraterrestrial landing and launch and rendezvous docking systems. The present state of

the art for earth landing systems is limited to a parachute recovery system with crushable impact attenuation structures. Since with such systems the human operator has limited manual vehicle control capability, the manual operations mainly involve positioning and aligning the vehicle with respect to wind drift. However, with subsequent developments, e.g., flexwing and parawing configurations, far greater operator involvement may be indicated. Automatic and manually controlled recovery aids will be used after landing. Included should be a radio, light beacons, radar chaff, dye markers, etc.

Extraterrestrial landing and launch systems will contain the retrograde propulsion, landing gear, guidance, and control units required to effect a soft landing on a body surface. The launch configuration employed will depend on the surface and atmospheric conditions of the body, but should, in all cases, include an entire launch module requiring minimum prelaunch checkout and offering maximum reliability. A rendezvous mission will require the use of special equipment and control configurations such as precision terminal guidance radar, throttleable and restartable propulsion systems and star trackers which can give azimuth and vertical attitude references with a precision of a few seconds of arc.

9. Mechanical Subsystem - All vehicles will require mechanical systems to effect interstage connections and separations. Also required will be mechanical means for jettisoning large landing gear equipment, umbilicals and non-reusable vehicle modules. Mechanical vehicle mating

and separation will be used for rendezvous docking missions. Contained in such systems will also be airlocks and their associated entry and egress controls. Earth and other landing systems will require mechanical shock attenuation mechanisms for crew safety.

10. Electrical Power - An elaborate electrical system will be employed to provide the required electrical power for environmental control, lighting, scientific equipment, propulsion, stabilization and control subsystems, communications, tracking and instrumentation, and navigation and guidance equipment. Redundant components will be required in critical areas for necessary reliability. Control and selection of the power sources and connected loads will be manual except for emergency relay systems.

11. Structural and Heat Protection - Structural design will provide for vehicle integrity with respect to aerodynamic loading and heating, vibration, noise, equipment mounting, crew space, and support. Manual checklist procedures may be required to monitor and check out some of these items. In other cases automatic sensors will provide inputs to monitoring and alarm devices. Of major concern in this subsystem will be radiation-shielding. Reliable and accurate sensors must be provided and warning and alarm systems must be included to insure maximum crew safety.

III. ACTIVITY ANALYSIS

A. General Approach

For purposes of analyzing operator participation in the system, a matrix has been developed which identifies functions as they relate to mission phases and vehicle subsystems. This framework enables the examination of functions and the development of information and control requirements in a systematic manner, phase by phase, subsystem by subsystem. The matrix is shown in Figure 1.

The matrix presents a comprehensive view of the functions to be performed, or conditions to be achieved, for a wide variety of space missions. The implicit assumption underlying the matrix entries is that these functions would, or could, be performed by man. The actual allocation of functions between man and machine rests upon a close examination of the functions to be performed and the relative effectiveness of man or machine in performing such functions within system requirements. In order to describe and analyze the range of functions which could be reasonably assigned to human operators in the accomplishment of this wide range of space missions, it is useful to develop a task taxonomy which also has some general applicability. Such a brief taxonomy is presented here.

Tasks assigned to an operator can be categorized into three major groups: monitoring (information), decision-making, and control (action). Within these broad categories, specific behavioral descriptions can be

generated which provide a framework for ordering the activities of spacecraft operators. Within this framework detailed information-decision-action sequences may then be formulated with direct display-control implications in the subsequent phases of this study.

The taxonomy as it will be used to describe operator activities in this context is as follows:

1. Monitoring and Checkout

   a. Routine Pre-Established Procedures for Inspection, Checkout and Calibration

      Tasks involving routinized activities performed in terms of standard operating procedures in a pre-determined sequential manner. Such tasks require a minimum degree of judgment and analysis and involve few, if any, alternative behaviors on the part of the operator.

      Examples:

      1) Checkout of equipment and vehicle systems

      2) Checklist sequences for equipment "in-tolerance": requirements and flight phases

      3) Checklist for adequacy of operation

      4) Procedures for equipment activation

      5) Inspection (equipment test points; visual observation)

   b. Positioning of Discrete/Serial Controls

      These tasks involve the manipulation of controls in an identifiable procedural sequence where the measurement emphasis is placed on sequential procedure and accuracy of positioning results.

Examples:

1) Activating equipment or subsystems

2) Tuning and channel selection in electronic equipment

3) Making power settings

4) Regulating air flow, temperature, pressure, etc., in Life Support Systems.

c. Obtaining Information from Dynamic and Multiple Source Displays

These tasks relate to the detection, identification and recognition of information from dynamic and multiple source displays. They include qualitative and quantitative readouts, and readouts involving complex relationships requiring the collation of multiple source information.

Examples:

1) Monitoring an event

2) Detection of deviations from normal readings

3) Use of displays in control activities

4) Multiple display interrogation.

d. Equipment and Instrument Adjustment

These tasks involve motor manipulations and adjustments that are not sequential or procedural in nature.

Examples:

1) Manipulating vehicle instruments - nav. equip., digital computer, etc.

2) Adjusting equipment tolerances, timing.

e. Information Source Utilization

Tasks relating to the utilization of informational materials which serve to support performance. Concern with the effective utilization of job aids which eliminate the need for memorization of sequences and the learning of specific information. Included here are the use of handbooks, information lists, tables and charts, etc.

Examples:

1) Time checks (elapsed time, time to next event, etc.)

2) Use of job aids in troubleshooting

3) Use of navigation aids (charts, celestial data tables)

f. Direct Observation of External Events

Activities associated with the determination of events external to the vehicle such as collision dangers, recognition of checkpoints and ground objects, weather observations, etc.

Examples:

1) Inspection of satellite (target)

2) Target spotting

3) Extra-vehicle observation (danger detection and weather).

2. Decision Making

a. Action Selection from among Alternate Choices

Tasks in this category involve activity associated with concept-using behavior. These may be influenced by formal or informal rules

of operation, priority or risk-bearing assessments, as well as uncertainty and incomplete information.

Examples:

1) Course-of-action selection

2) Go/No Go decisions

b. Computational/Measurement Sequences for Determining Status

These tasks concern computational subroutines associated with problem-solving behavior and status determination.

Examples:

1) Navigation computation

2) Power/energy management

3) Time

c. Command/Control Actions (Decisions) based upon Processed Multiple Information

These tasks involve the integration and processing of complex information, the results of which are relatively simple acts. Involved here are priority decisions and alternate courses of action.

Examples:

1) Initiation of emergency action

2) Initiation/termination of significant phases of flight

3) Evaluation of malfunction or damage

4) Evaluation of mission progress

5) Determination of substandard conditions

d. Location of Malfunctions in Complex Equipment

These tasks are concerned with the sequential activity involved in fault localization including problem-solving and decision-making behavior.

Examples:

1) Subsystem troubleshooting

3. Control

a. Tracking

These tasks deal with psychomotor activity emphasizing the response (output) aspects of performance in continuous interaction with stimulus (input) aspects. Involved are compensatory and pursuit tracking in one, two, or three dimensions.

Examples:

1) Positioning of vehicle (thrust, direction control, flight path control, turn corrections)

2) Activating individual propulsion devices

b. Multiple Control Actions

These tasks are concerned with carrying out sequences of action necessary to change system performance. Involved may be several discrete continuous control and/or adjustive movements employed in activating, regulating and modifying performance through controlling devices. While the stimuli or cues are simple, the actions are complex.

Examples:

1) Booster/rocket ignition

2) Manual control of vehicle during stages of flight

3) Activation of emergency modes

4) Manual to automatic control modes

B. Information and Control Requirements

The task classification described above will be used in the next phase of this study to determine information and control requirements for the primary subsystems of the manned space vehicles. Greatest attention will be devoted to the navigation and control functions with consideration given to related subsystems insofar as they affect the navigation and control problem. Information-decision-action sequences will be developed to the extent possible without limiting the results to a specific vehicle configuration or set of equipment. Detailed analysis will be performed on the information requirements thus generated to convert these requirements to human factors criteria in the display of navigation and control information.

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		SUBSYSTEM / MISSION PHASE	NAVIGATION AND GUIDANCE 1. Inertial 2. Optical 3. Computers 4. Radar 5. Ground telemetry	ATTITUDE STABILIZATION AND CONTROL	PROPULSION 1. Vernier (Attitude) 2. Mission	ENVIRONMENT CONTROL AND LIFE SUPPORT 1. Internal atmosphere 2. Water 3. Nutrients 4. Sanitary facilities 5. Personal protection	COMMUNICATION 1. Voice communication with earth 2. T. V. transmission 3. Crew intercom 4. Earth telemetry 5. Rescue and recovery	SCIENTIFIC INSTRUMENT	EMERGENCY AND ABORT 1. Launch escape 2. Mission abort	LANDING AND LAUNCH 1. Earth landing 2. Extra-terrestrial landing 3. Extra-terrestrial launch 4. Rendezvous (docking)	MECHANICAL 1. Umbilicals and disconnects 2. Airlock 3. Docking 4. Earth impact equipment	ELECTRIC POWER 1. Main power cells 2. Re-entry and recovery battery system 3. Electrical ignition power	STRUCTURAL AND HEAT PROTECTION
COMMON		PRELAUNCH	1. Checkout equipment, controls and displays for proper operation 2. Check preprogramed trajectory with ground control	1. Checkout equipment and all modes of operation 2. Activate auto-attitude control systems for launch	1. Checkout all systems 2. Monitor booster checkout with ground control	1. Checkout all subsystems 2. Activate cabin environment control--initiate internal atmosphere starting sequence 3. Checkout pressure suits for proper operation 4. Assume launch positions 5. Fasten restraints	1. Checkout all subsystems with ground control 2. Make final check 3. Initiate final countdown	1. Checkout equipment for flight as applicable	1. Checkout and monitor launch escape warning system	1. Checkout all modes	1. Test and checkout	1. Check power system outputs . Fuel cells . Auxiliary batteries . Emergency batteries 2. Switch to internal power 3. Check bus voltages 4. Check power flow displays	1. Arrange cabin for launch 2. Secure hatch; checkout vehicle for structural integrity
		EARTH LAUNCH	1. Monitor trajectory acceleration and velocity 2. Check trajectory parameters for orbit entry 3. Program corrections as required	1. Monitor attude during boost 2. Prepare to switch to manual attitude control prior to injection 3. Assume attitude control 4. Initiate attitude corrections for orbital entry	1. Monitor launch instruments 2. Monitor separation of booster stages 3. Monitor and report final booster stage separation	1. Monitor environmental control system, maintain balance of internal atmosphere: · Temperature · Relative humidity · Total pressure · Oxygen partial pressure · Oxygen quantity · Toxic constituents 2. Monitor personal protection subsystems; acceleration, vibration and radiation levels, noise levels	1. Maintain voice communication with ground control 2. Report booster separation to ground control	1. Monitor and record data as required by mission	1. Monitor warning system 2. Preselect successive abort modes		1. Insure proper disconnect of all umbilicals 2. Check proper separation of last stage	1. Monitor system 2. Adjust power settings as required 3. Activate electrical ignition system for injection	1. Monitor for vehicle integrity
		EARTH ORBIT	1. Assume full navigation and guidance control 2. Confirm orbit . Position . Velocity . Orbital parameters 3. Program corrections if required	1. Check attitude references 2. Correct attitude as required	1. Monitor thrust program for orbit entry 2. Check all active propulsion systems 3. Assume full onboard propulsion control 4. Activate vernier control for attitude	1. Monitor and maintain balance: · Internal atmosphere · Personal protection 2. Maintain atmosphere regeneration system 3. Maintain water regeneration system 4. Activate artificial gravity system or compensation system	1. Maintain voice communication with ground control 2. Receive and transmit telemeter data as required 3. Check extra- and intra-vehicle communications 4. Report pertinent orbital data to ground control	1. Monitor and record data as required by mission	1. Monitor malfunction and warning system		1. Check docking equipment and airlock for rendezvous missions	1. Monitor system 2. Check power-flow display 3. Adjust electric power for normal free-fall condition	1. Check vehicle integrity
MISSION SPECIFIC	RENDEZVOUS	ORBITAL TRANSFER	1. Determine target orbit 2. Determine position and velocity of target (may be derived from ground tracking stations) 3. Determine own vehicle orbit, position and velocity 4. Determine time to initiate transfer 5. Program maneuver	1. Correct attitude as required by orbital transfer thrust program 2. Monitor attitude throughout transfer period; initiate corrections as required	1. Prepare thrust program for transfer (magnitude, start and cutoff times) 2. Orient thrust in conjunction with attitude control 3. Initiate thrust program	1. Assume restraint position 2. Check cabin and suit environment 3. Monitor and maintain system balance: · Internal atmosphere · Personal protection	1. Receive and verify target navigation and guidance parameters 2. Verify own maneuver and thrust program		1. Monitor warning and malfunction system	1. Initiate final injection countdown	1. Checkout coupling and mating devices	1. Checkout electric power system: Mechanization of sensors and maneuvering computer Activation of control jets ignition system 2. Check power flow display	1. Check vehicle integrity 2. Determination heat protection requirements
		DOCKING	1. Switch to docking mode 2. Check and determine: . Range . Range rate . Angular orientation of sight-line between target and own vehicle . Direction information 3. Program maneuver sequence	1. Monitor and correct attitude	1. Switch to docking propulsion system 2. Initiate thrust program(s)	1. Monitor and maintain balance: Internal atmosphere Personal protection 2. Activate environment control system in docking vehicle as required by mission	1. Continuous communications with ground control		1. Monitor warning and malfunction system	1. Prepare for docking 2. Initiate docking control sequence 3. Perform mission tasks: fueling, module mating, personnel transfer, etc.	1. Activate and control coupling and mating mechanism 2. Position airlock	1. Adjust power load and flow for rendezvous 2. Activate airlock electric power	1. Monitor vehicle integrity (may be critical during mating and airlock control operations)
	LUNAR OR PLANETARY	TRANSBODY (MIDCOURSE)	1. Assess accuracy of trajectory parameters 2. Program and initiate mid-course corrections as required 3. Calculate positions and velocities and compare with programed and telemetered data 4. Switch to approach mode for "flyby" missions	1. Maintain required attitude for navigation and scientific observations 2. Maintain close attitude tolerance during thrust application	1. Setup and schedule thrust programs for midcourse corrections 2. Initiate thrust program for midcourse corrections	1. Monitor and maintain: Internal atmosphere Personal protection 2. Initiate work rest cycle: Monitor and utilize: Water system, Nutrients, Sanitary facilities 3. Activate artificial gravity system 4. Maintain close check of radiation levels	1. Maintain periodic communications and status reports to ground	1. Monitor, plot and predict radiation intensity 2. Perform in-flight observations and scientific activities · Radiation · Astronomical · Biomedical · Psycho-physiological	1. Monitor warning and malfunction system			1. Monitor and adjust in accordance with power-flow diagram 2. Check and activate ignition power for midcourse corrections	1. Monitor
		CIRCUMBODY PASSAGE (FLYBY)	1. Establish and assess transplanet trajectory 2. Calculate position and velocity 3. Program final midcourse correction 4. Calculate velocity and determine retrograde if required	1. Maintain attitude as required	1. Prepare for retrograde as required	1. Monitor and maintain balance as above	1. Maintain periodic communications and status reports with ground	1. Perform in-flight observations and scientific activities 2. Photograph and record data and observations	1. Monitor warning and malfunction system			1. Monitor and adjust in accordance with power-flow display	1. Monitor
		BODY ORBIT	1. Check body-observation and navigation equipment 2. Prepare to retrograde into planet orbit; determine . Vehicle trajectory . Desired planet orbit 3. Confirm planet orbit 4. Correct orbit as required 5. Select and confirm landing site for planet landing missions	1. Change attitude as required 2. Maintain attitude	1. Prepare propulsion system for retrograde maneuver . Establish retrograde parameters 2. Initiate retrograde program for body orbit	1. Monitor and maintain as above	1. Maintain periodic communications and status reports with ground	1. As above	1. Monitor warning and malfunction system			1. Monitor as above	1. Monitor
		BODY LANDING	1. Confirm planet landing sequence: . Time, thrust, and attitude . Position and velocity . Orbit parameters 2. Activate landing system navigational aid(s) . Beacon . Radar . Other	1. Attain required landing attitude 2. Maintain close tolerances	1. Determine retrograde parameters for final orbit and landing 2. Confirm thrust program and time to initiate 3. Initiate thrust program	1. Prepare for retrograde 2. Check pressure suits 3. Take landing positions 4. Fasten restraints 5. Prepare to leave vehicle for exploration	1. Report mission status to earth	1. Perform scientific activities as per mission requirements Atmospheric and surface characteristics, etc.	1. Monitor warning and malfunction system	1. Check landing system and activate 2. Check landing site and confirm	1. Check impact system	1. Checkout in preparation for landing 2. Activate power sytems required for landing	1. Make vehicular check for structural damage . Meteorite . Thermal . Other
COMMON		ATMOSPHERIC RE-ENTRY	1. Establish re-entry conditions: . Entry corridor . Position . Velocity . Trajectory 2. Begin re-entry countdown 3. Fix position and monitor critical navigation parameters 4. Establish desired landing site	1. Establish re-entry attitude 2. Maintain close attitude tolerance during re-entry thrust 3. Following burnout vary attitude to achieve desired landing point	1. Perform re-entry check sequence 2. Establish and schedule required thrust application 3. Initiate thrust program 4. Monitor thrust program	1. Prepare vehicle for re-entry 2. Assume re-entry positions; fasten restraints 3. Close monitoring of: · Decompression · Noise Level · Vibration · Acceleration · Radiation 4. Monitor environmental system	1. Alert earth control centers 2. Communicate re-entry information 3. Maintain communications with ground		1. Monitor warning and malfunction system	1. Perform final check of landing and recovery systems 2. Activate landing system (parachutes, flexwing, parawing, etc.) 3. Monitor and control landing system as required	1. Check earth impact system	1. Monitor and adjust in accordance with power-flow display 2. Switch to re-entry and recovery power sytem 3. Monitor all buses for critical load	1. Check vehicle integrity 2. Prepare for re-entry 3. Monitor re-entry displays
		EARTH LANDING AND RECOVERY	1. Verify landing site	1. Monitor roll orientation prior to impact 2. Monitor automatic attitude and override prior to impact	1. Shut down all propulsion systems	1. Loosen restraints 2. Remove pressure suit 3. Prepare to leave vehicle	1. Maintain communications 2. Communicate landing position 3. Report crew and vehicle status after impact		1. Monitor warning and malfunction system	1. Initiate landing system release at impact as required 2. Check landing situation 3. Deploy recovery aids as scheduled	1. Fire pyrotechnics as required	1. Shut down power prior to vehicle egress	1. Monitor

Figure 1. MISSION ANALYSIS